



GE Fuel Cells Overview

ARPA-E Workshop

1/26/2017

GE-Fuel Cells | Overview

About us

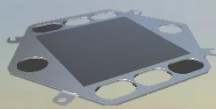
GE-Fuel Cells designs, develops and manufactures solid oxide fuel cell systems that provide businesses and communities around the world the ability to efficiently generate clean, reliable power at or near the point of use.

A start-up within GE: all of the speed, agility and focus of a small start-up with access to all the strength of a big company

- Internal incubation with independent leadership
- Fastworks approach drives speed to market & customer value
- Ramping up off site facility with pilot manufacturing capability

Innovating to address the fuel cell cost challenge

Additive manufacturing ...



*Low cost materials
Simplified sealing
Scalable*

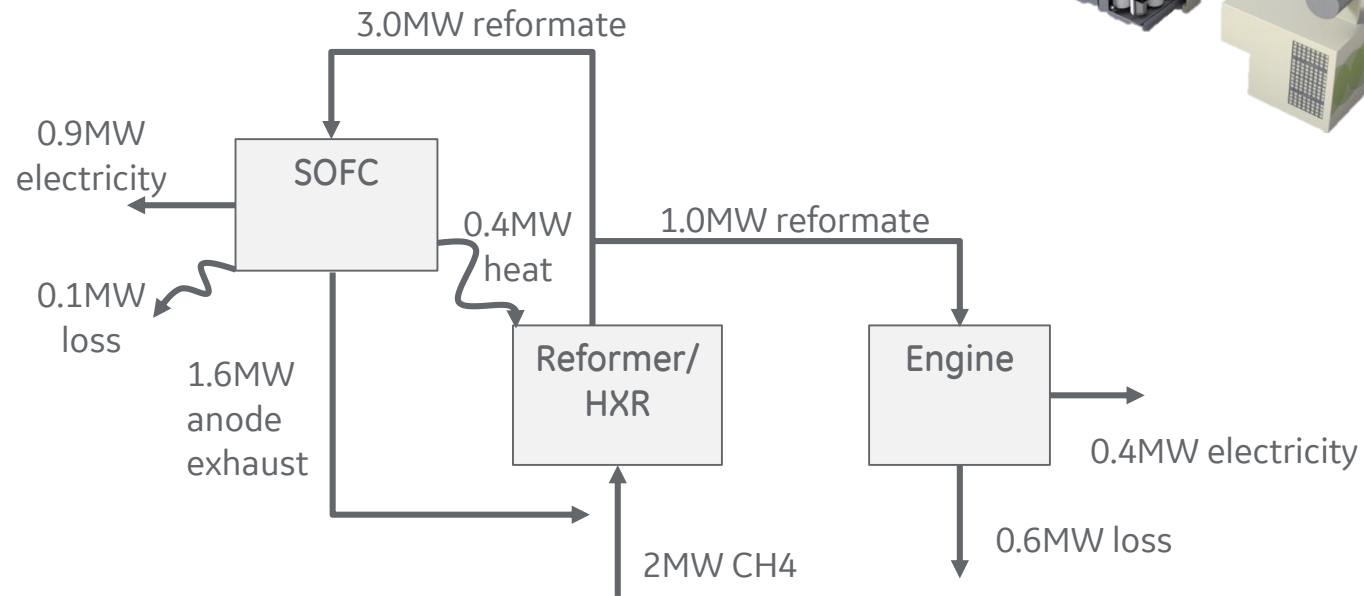
... Combined cycle design



*Efficient
Modular
Clean*

SOFC/Engine Combined Cycle

Conceptual heat and energy balance



$$\text{Efficiency} = (0.9 + 0.4) / 2 = 0.65$$

- MW Electrical output
- >60% Efficiency
- Natural gas fueled
- Turn down capability
- Low GHG emissions

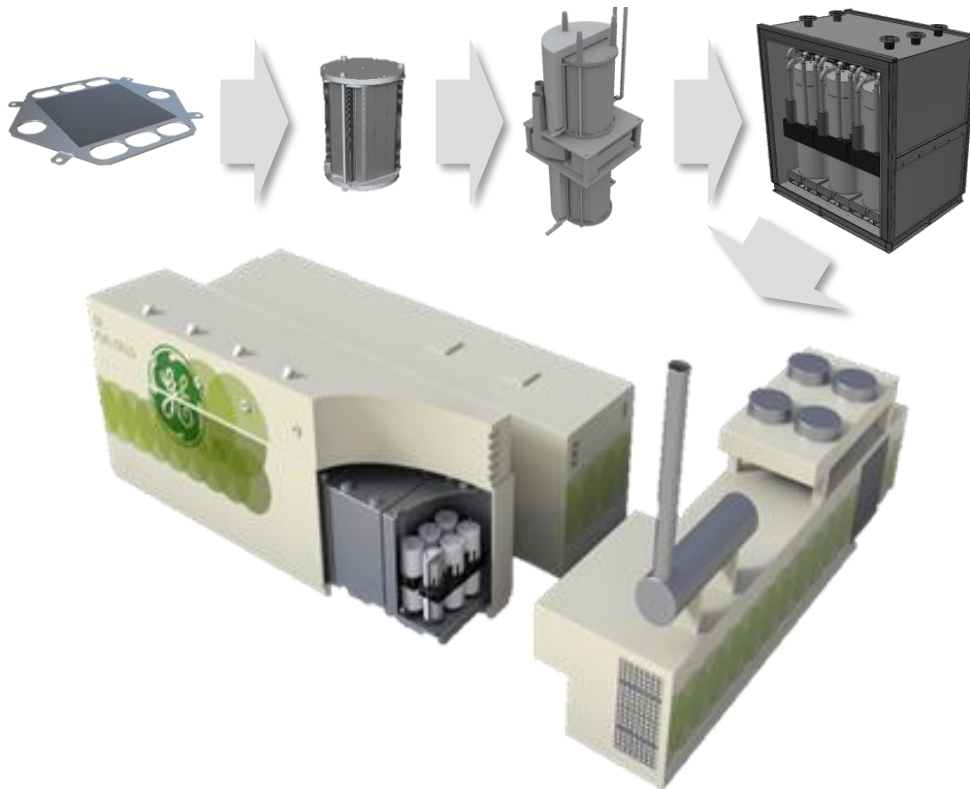
Clean reliable on-site energy



GE-Fuel Cells | Overview

Initial plan: Launch as fast as possible as an independent business

Launch concept: 1.3MW HSOFC system



Progress: Designed, built & tested 50kW & HSOFC pilot systems



50kW technology pilot

1.3MW HSOFC pilot

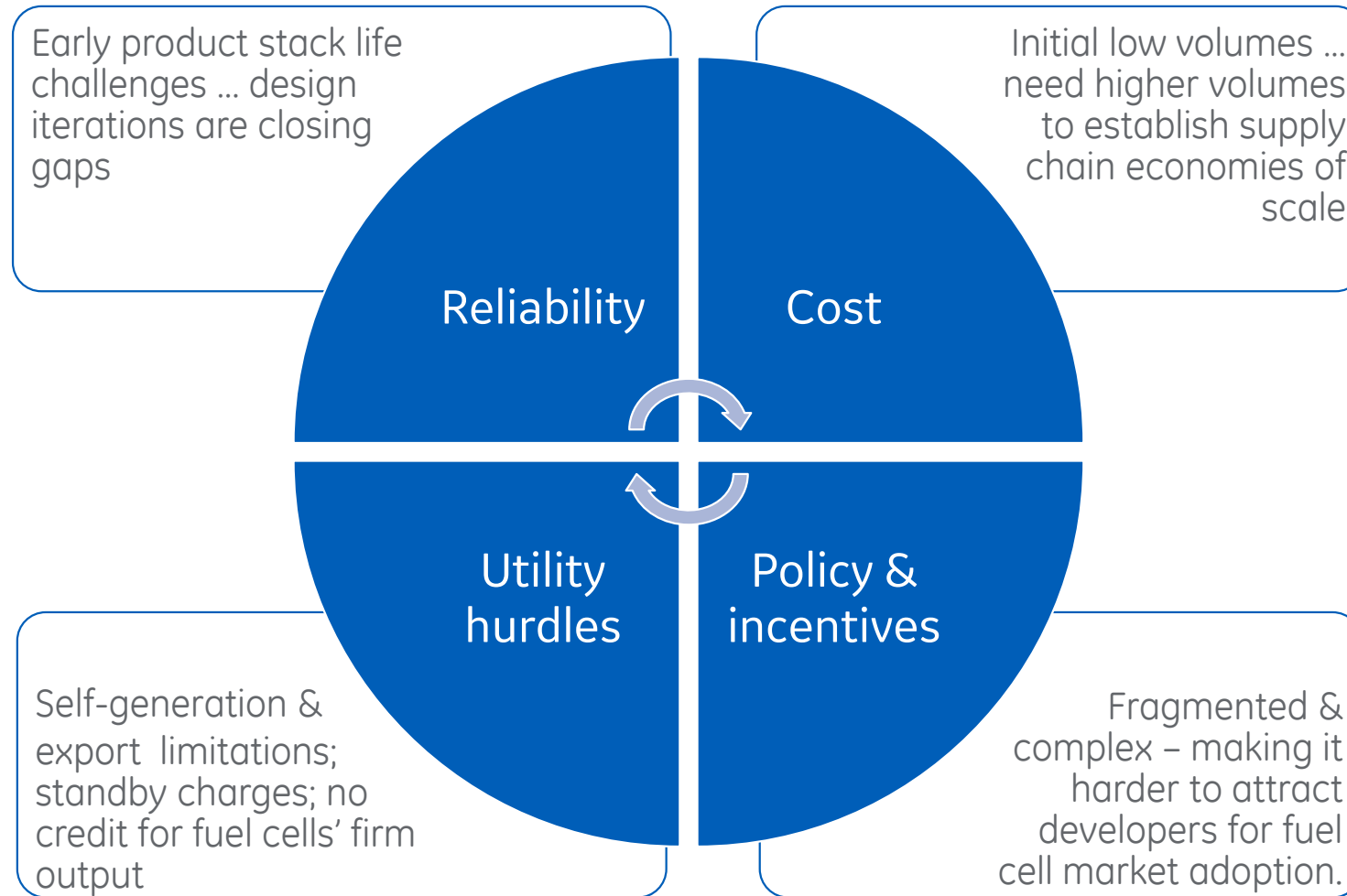


- Validated MVP cost & performance
- Identified launch customers/projects

Lessons learned: Separate fuel processing unit drives cost & reliability challenges



Challenges to meeting fuel cell potential



GE-Fuel Cells | Proprietary advantage

Application of known additive manufacturing process

Taking GE's thermal spray process



... to manufacture fuel cells ...



... & improve CAPEX & OPEX

- Low cost material
- Low capex factory
- Simplified sealing
- Larger cell area
- Robust process

Leveraging the GE experience to develop cost effective SOFC systems



GE-Fuel Cells | Initial commercial product

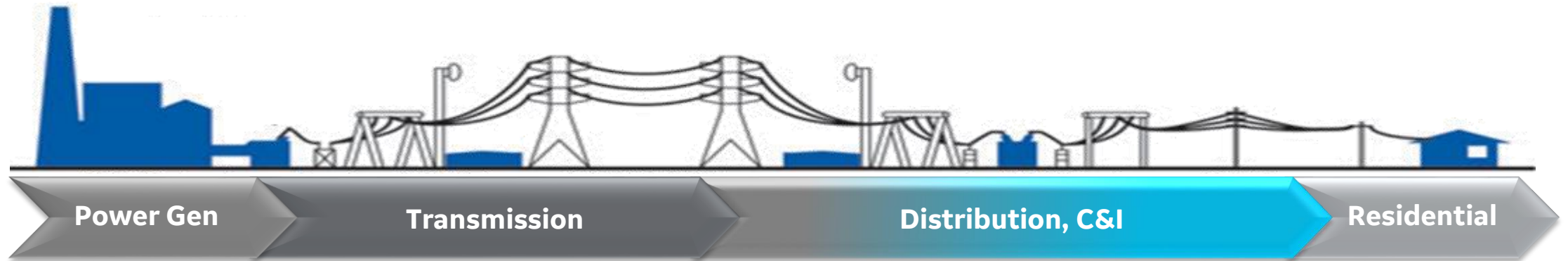


- Electrical output: 1.0MW
- 60% Efficiency
- Natural gas fueled
- Minimal site installation
- Low GHG emissions

Clean reliable base-load distributed power at grid parity



Why do customers buy fuel cells?



Wholesale market

Retail market

Utilities

- T&D investment deferral
- Congestion relief
- RPS targets / credits
- Emissions
- Renewable integration

IPP's




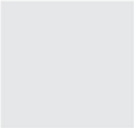
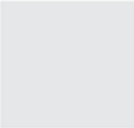
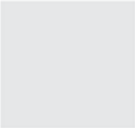


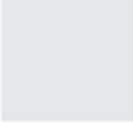

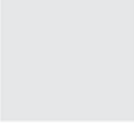
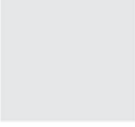






- Return on investment
- Renewable standards/credits
- Access aux markets
- Renewable integration

C&I users

- Delivered energy cost
- Energy security
- Peak/demand charge mgmt.
- Clean energy targets & policy
- US Executive Orders

Drivers vary by customer, application and region

Fuel cells vs. traditional distributed energy resources

		Modular	Ultra-Low Emissions	Dispatchable	Electrical Efficiency > 60%	Net Water Production
Solar PV						
Gas Engine						
Fuel Cell						

Fuel cells complement renewables in DG space

Power dense applications

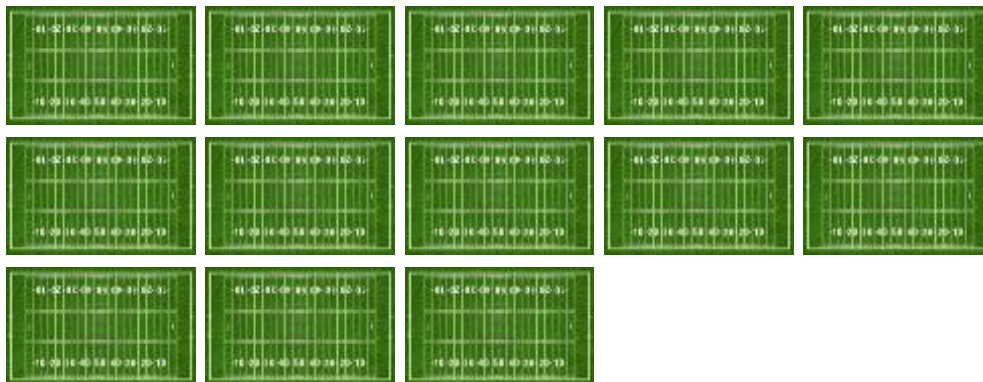
Footprint
to deliver 10,000MWhrs/yr.



<1 end zone

vs.

13 football fields of PV



Renewable Smoothing
& Ancillary Services

Dispatchable
provide power when needed



GE-Fuel Cells SOFC vs. the grid

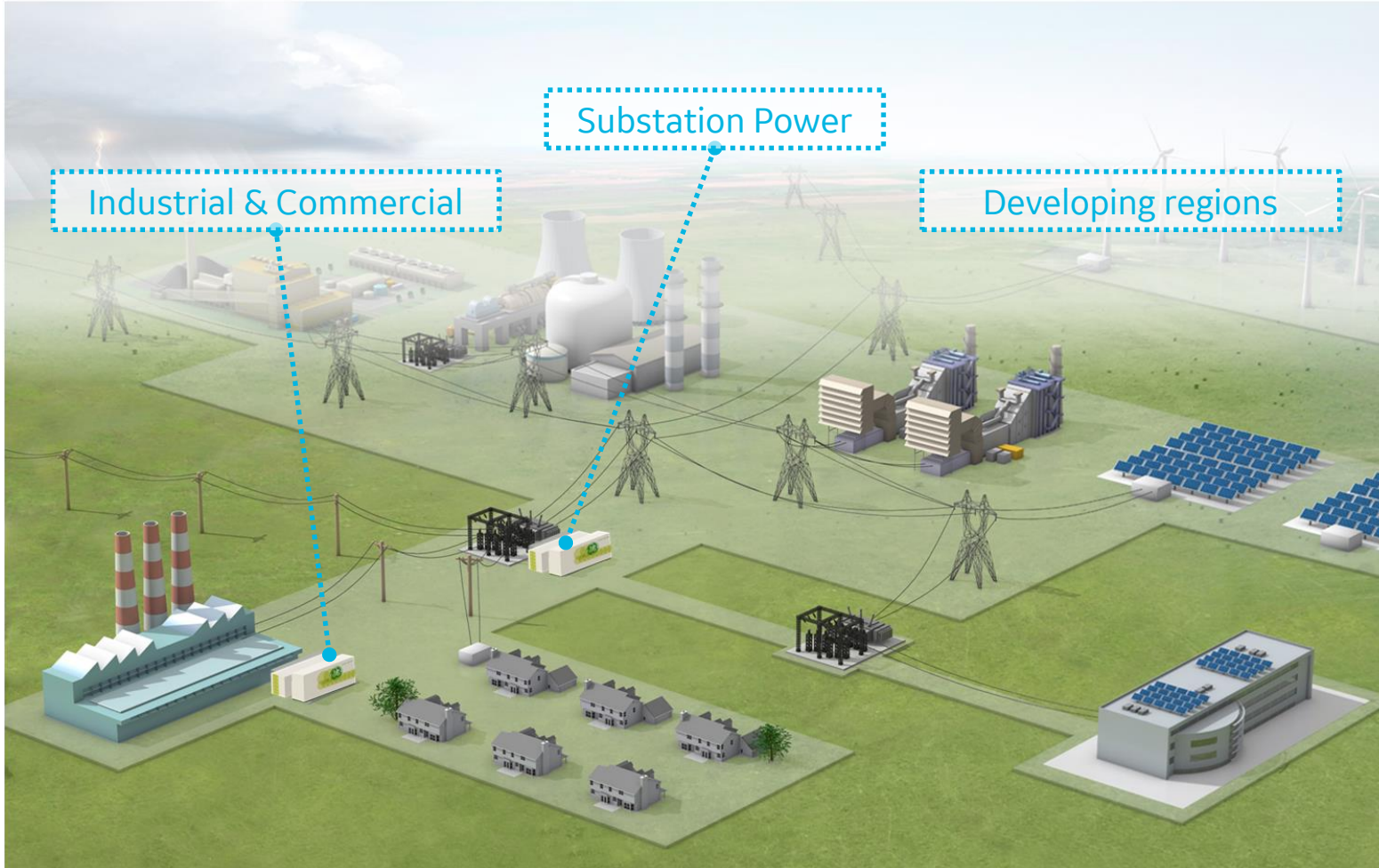


	Delivered Efficiency	CO ₂ (lb./MWhr.)	NOx (lb./MWhr.)	SOx (lb./MWhr.)	Water Consumption (gal/MWhr.)
US Grid	~35%	~1,200	~1.2	~2.5	~2,000
Korean Grid	~43%	~1,100	~1.5	~0.7	~1,710
Gas Engine	~38%	~1,180	~1.7	<1	-
MCFC	~47%	~980	~0.01	Negligible	~190
GE-FC SOFC	60%	~662	< 0.01	Negligible	~60 produced

Sources: eGRID 9th edition, DOE & GE Marketing



GE-Fuel Cells | MW scale SOFC applications



Distributed Generation

- **Industrial & Commercial**
 - On site power
 - High efficiency
 - Reliability
 - Low emissions
- **Substation Power**
 - Power where its needed without additional transmission lines
 - RPS/REC compliance
- **Developing regions**
 - Build out power without creating large T&D network

GE-Fuel Cells | Commercialization plan

Development & Test

50kW Technology Pilot

Product Demonstration

MW Product Demo

Limited sales

Selective Launch

Targeted Geographies

Scale



Building block pilot: 50kw

- Controls development
- Test and evaluation



Product demo: sub-MW

- Operational testing
- Automated controls



Selective launch: 1.0MW

- Small number of systems
- Preferred partners



GE-Fuel Cells | Summary

Combined cycle SOFC systems



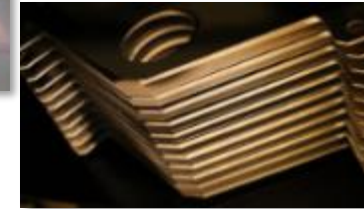
- **Efficient:** 60% system efficiency
- **Modular:** 1-10MW of distributed power
- **Clean:** Low GHG emissions

Differentiation: additive manufacturing

Applying GE's thermal spray process ...



... to produce fuel cells ...



... and improve CAPEX & OPEX

- **Low cost:** Materials & factories
- **Durable:** Simplified sealing
- **Scalable:** Larger cell area

Why is GE-Fuel Cells different?

- **Low costs cells & factories:** Materials & processes
- **Leveraging industry learning:** Partnering & purchasing vs. developing
- **Access to the GE Store:** Technology, operational & commercial support



